

How can PBL promote critical thinking skills in biology material? A systematic literature review in reputable journals

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Abstract: The Merdeka Curriculum requires teachers to apply various learning models, including PBL, to achieve learning objectives, including critical thinking skills. However, in the context of biology learning, the application of the PBL model is rarely considered to improve students' critical thinking skills, and research on this is still limited. Therefore, this research is essential because there is no complete analysis of the impact of the PBL learning model on critical thinking skills in biology indexed by Scopus. This study uses the SLR method to investigate the effect of the PBL learning model on students' critical thinking skills in biology material. This research method follows the PRISMA model for selecting articles based on specific criteria in the SCOPUS database. The research results show that presentation and discussion methods dominate biology learning, while there is a lack of attention to students' critical thinking and a lack of electronic teaching materials. On the other hand, problem-based learning helps students understand and apply biological material and develop critical thinking skills by emphasizing the application of knowledge, analysis, synthesis, and evaluation and involving students in group discussions to motivate critical thinking. Research shows that PBL effectively improves students' critical thinking, supported by various learning models and media that strengthen students' critical thinking skills. In conclusion, applying the PBL model allows students to focus on specific topics, understand scientific concepts, and overcome challenges through data analysis, hypothesis generation, and deductive reasoning. This model encourages critical thinking and active participation of students. Teachers are expected to be able to use various learning models to improve students' thinking abilities.

Keywords: Biology; critical thinking skill; learning media; learning methods; PBL model

1. Introduction

The Merdeka Curriculum emphasizes the importance of using learning models to achieve learning goals. The learning model can provide meaningful learning experiences for students (Cahya et al., 2023; Usman et al., 2021; Usman, Eurika, Priantari, et al., 2023). One of the learning models that is the main focus is the PBL (Problem-Based Learning) learning model (Ahdhianto et al., 2022; Suhud et al., 2023). Further developing students' critical thinking skills is one of the learning goals that must be achieved (Prahani et al., 2023). Students' critical thinking skills must be empowered in the learning process because critical thinking skills help students understand and evaluate information (Mar, 2021; Peters et al., 2002). Furthermore, biology is learning material that cannot be separated from teaching students to behave and think scientifically (Mordeno et al., 2019; Riley, 2021; Shonkoff, 2020). Thus, the use of learning models such as PBL is an effective means of supporting efforts to achieve comprehensive and sustainable learning goals (Braga et al., 2022; Du et al., 2022; Hsiao et al., 2022; Poursharif et al., 2021).

Even though the role of students' critical thinking skills has been recognized in the learning process, to date, the learning process still tends to be teacher-centered (Amini et al., 2019; Kranzfelder et al., 2020; Matsuyama et al., 2019; Nurlaila & Lufri, 2021; Pebriawati et al., 2019; Resnita et al., 2019; Usman et al., 2023). Teacher-centered learning can result in low development of students' critical thinking abilities (Mufit et al., 2023; Nugraha et al., 2016; Rachmawati et al., 2023). Students' low essential level of thinking is caused by the lack of use of models in the learning process (Macedo et al., 2020; O., 2020; Pratomo et al., 2021; Rozenszajn et al., 2019). Especially in learning Biology material, teachers pay less attention to applying learning models such as PBL to empower students'

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critical thinking abilities (Awati et al., 2024; Hidayati et al., 2023; Kundariati et al., 2023; Puspita et al., 2024; Putri & Suwono, 2023; Salmah et al., 2023; Sungur & Tekkaya, 2006). Several research reports state that the PBL learning model can empower students' critical thinking skills (Luthfiyah et al., 2019; Sajidan et al., 2021; Santuthi et al., 2020; Utami et al., 2023). However, it is still rare to find research that examines the PBL learning model in empowering biology students' critical thinking skills. This shows gaps that need attention. Therefore, this research aims to fill the gap by prioritizing learning models in achieving learning goals.

This research is needed because, until now, there has been no analysis of Scopus-indexed review articles that specifically discuss how the PBL learning model encourages critical thinking skills in Biology students. For example, research results Adawiyah et al., (2023), Asyari et al., (2016), Azizah & Aloysius (2023), Muhfahroyin et al., (2023), Ibrahim et al., (2020), Isnaeni et al. (2021), and Priyadi and Suyanto (2019) do not focus on analyzing article reviews but rather on empirical research or theoretical studies. The question to be answered in this research is how the PBL learning model can encourage Biology students' critical thinking skills. So, this research analyzed relevant information from accredited scientific literature. It is hoped that the research results can contribute to teachers' understanding of the role of learning models in encouraging the achievement of learning goals.

2. Material and Methods

2.1 Study Type

This study utilizes a Systematic Literature Review (SLR), specifically developed to systematically discover, evaluate, and analyze pertinent material found in the literature or references. The objective is to investigate research inquiries and thoroughly examine the results (Susetyarini & Fauzi, 2020). SLR aims to present a comprehensive overview of the existing information or discussion related to the study subject. This approach has also been employed by other writers in Indonesia (Husamah et al., 2022).

2.2 Research Question (RQ)

The design of the research topic has a vital role in establishing the scope and providing a clear focus for the investigation. Research questions were formulated to answer the specific needs of the selected topic, namely: (1) important information related to documents, (2) how does the PBL learning model influence the development of students' thinking skills on biology material, (3) what are the students' activities in the PBL learning process.

2.3 Search article and inclusion criteria

We used the phrase "PBL and critical thinking skills and biology" in the SCOPUS database search. The collected data was saved in RIS format and loaded into Reference Manager (Mendeley). The search strategy in SCOPUS included the following criteria: Document Search: "PBL," "critical thinking skills," and "biology." Year: 2020-2023. Document type: conference paper, article, conference review. Source type: conference proceedings, journal. English language. The selection criteria were based on the PRISMA model, as Gallagher et al., (2016) described. Inclusion criteria consisted of articles that met the following specifications: (1) publication date between 2020-2023, (2) published in English, (3) was a research or original article, and (4) included only final articles. The inclusion and exclusion procedures were organized as described in Figure 1.

Figure 1, clearly shows that a total of 203 documents were first discovered. Therefore, we focused our attention on documents published from 2020 to 2023. From these results, 113 documents met the specified requirements, while 90 other documents did not meet the specified criteria. The next stage was a special selection within a particular subject area, which resulted in 84 documents that met the requirements, while the other 29 documents did not meet the criteria. The next step was to determine the type of document, such as articles, conference papers, and conference reviews, which resulted in 51

documents that met the requirements and 33 other documents that did not meet the criteria. In the final selection stage, we searched based on biological material, where only 14 documents fulfilled the established criteria and were included in the analysis. In comparison, another 37 documents did not meet the requirements and were excluded from the analysis.

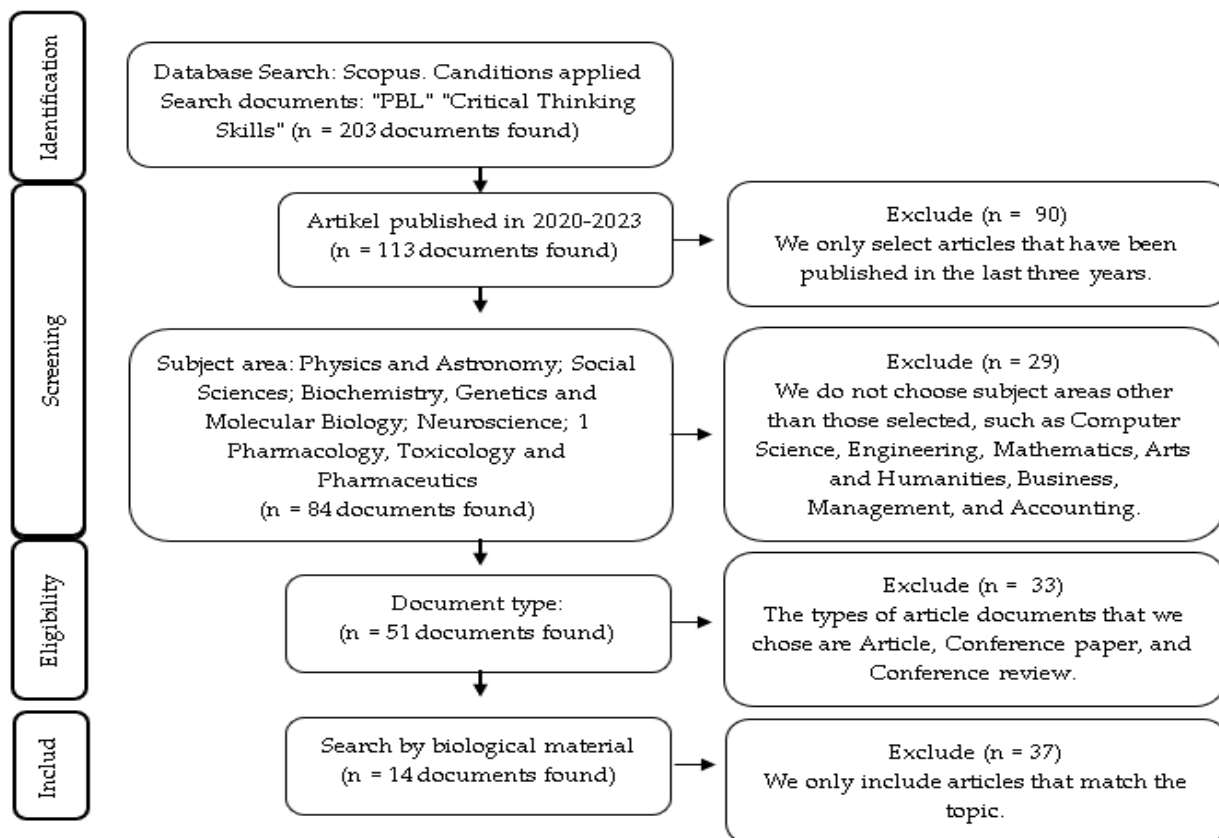


Figure 1. Systematic review flow diagram.

3. Results

Based on relevant research, we can obtain necessary information regarding the influence of the PBL learning model on the development of student's critical thinking skills and their learning activities in the PBL learning process. The results of this research are usually compiled and presented in table form, which includes columns such as references, type of research, data collection instruments, data analysis methods, and results. Table 1, is a summary and presentation of relevant information from research that has been conducted previously.

Table 1. Results of article analysis

References	Type of research	Research subject	Data collection instruments	Data analysis methods	Results
(Asyari et al., 2016)	CAR	Undergraduate students	observation sheet and test sheet	mean	The application of PBL and GI can encourage students to think critically, especially in the context of solving environmental problems. Through PBL and GI, students carefully plan, develop strong arguments, formulate questions and problems correctly, analyze in-depth, and provide sustainable solutions to environmental problems. Furthermore, students understand ecological problems and are trained to develop critical skills.

References	Type of research	Research subject	Data collection instruments	Data analysis methods	Results
(Arsih et al., 2021)	Quantitative research. Types of quantitative research are quasi-experimental designs	Undergraduate students	test sheet	ANCOVA	The research results of the RANDAI learning model (Minangkabau culture and PBL) influence the critical thinking abilities of pre-service biology teachers. Furthermore, there are significant differences in critical thinking between participants in RANDAI, Problem-Based Learning, and conventional classes. In the learning process, students carry out RANDAI learning steps, which consist of six learning steps, namely: (1) Reciting, (2) Analyzing the problem, (3) Narrating the solution, (4) Doing the solution, (5) Assessing the solution, and (6) Implementing the solution. Students focus on various contextual issues but still uphold the values and principles of Minangkabau culture. Furthermore, the learning atmosphere is relaxed at RANDAI because the Kaba (story) performance can motivate students. Motivation plays a vital role in the classroom; students who excel.
(Priyadi & Suyanto, 2019)	Quantitative research. Types of quantitative research are quasi-experimental designs	X Grade SHS students	test sheet	t-test	PBL with Fishbone Diagram (FD) effectively develops students' critical thinking skills. The PBL with FD learning process means that before solving a problem, students must identify and understand the cause of the problem, which can make solving the problem easier. Student activities in PBL with FD are training students to analyze, find, and identify factors that influence a problem, determine more straightforward solutions, build their knowledge, and express and accept other people's opinions.
(Jirana et al., 2020)	Quantitative research. Types of quantitative research are observation studies	SHS Undergraduate students	observation sheet	t-test	There is an influence of applying the PBL model on critical thinking skills and stimulating students' creativity as prospective biology teachers. They are encouraging students to be more active and responsible in carrying out their duties as preparation to become professional teacher candidates.
(Adawiyah et al., 2023)	Quantitative research. Types of quantitative research are quasi-experimental designs	XI Grade SHS students	test sheet	ANCOVA	PBL, assisted by Google Workspace, can improve students' critical thinking skills. Furthermore, the average increase in score for the experimental class was 90%, and 56% for the control class was 56%. For each indicator of critical thinking skills, the increase in scores in the experimental class ranged between 19%-35% and 8%-23% in the control class.
(Azizah et al., 2020)	Quantitative research. Types of quantitative research are quasi-experimental designs	XI Grade SHS students	test sheet	ANCOVA	Students' critical thinking skills increased by 79.91% through RICOSRE, 19.00% through PBL, and 5.15% through conventional learning models. RICOSRE significantly impacts students' critical thinking abilities, so RICOSRE is highly recommended for biology learning.
(Miterianifa et	Qualitative	unidentified	unidentified	Percentage-	Based on the results of the meta-analysis, it was found that

References	Type of research	Research subject	Data collection instruments	Data analysis methods	Results
al., 2019)	research	ed		ge	the effect size, the average influence of applying the problem-based learning model on students' critical thinking abilities, was 1.2. This means that problem-based learning contributes 83.45% to improving students' abilities in physics, chemistry, and biology subjects. This means problem-based learning contributes 83.45% to enhancing students' physics, chemistry, and biology thinking abilities. The PBL model learning process focuses on selected problems so that students learn concepts related to the problem and scientific methods for solving problems. So that students gain learning experiences related to the skills of applying scientific methods in problem-solving and developing critical thinking patterns. With PBL, students can create ideas to challenge what is in learning (physics, biology, and chemistry).
(Boleng et al., 2017)	Quantitative research. Types of quantitative research are quasi-experimental designs	XI Grade SHS students	test sheet	ANCOVA	The learning model influences students' critical thinking abilities. The PBL model provides an average value of student learning outcomes for critical thinking skills that is 73.81% higher than conventional learning. Furthermore, PBL is proven to have the potential to empower and equalize students' critical thinking skills, which cannot be done with traditional learning. Applying PBL learning syntax allows students to choose ways to collect data according to their needs in the data collection process. Students can determine specific methods they think can be used to solve the previously formulated problems. They analyze and synthesize data, develop hypotheses, apply deductive reasoning, and draw conclusions. They will also create appropriate strategies and find solutions to their problems.
(Fitriani et al., 2020)	Quantitative research. Types of quantitative research are quasi-experimental designs	X Grade SHS students	test sheet	ANCOVA	PBLPOE has a more significant influence on students' critical thinking skills than PBL and POE. Furthermore, PBLPOE and PBL can improve students' critical thinking skills in the classroom. PBLPOE syntax (which was the combination of PBL and POE learning steps) consisted of six main activities: (1) the teacher distributed a text, and the students actively formulated questions based on the book; (2) the students were guided to sit in groups and select appropriate questions to discuss, (3) the teacher helped the students make predictions based on the problems, (4) the teacher facilitated the students' group and individual investigations, (5) the students presented the results of the investigations and compared them with the predictions, and (6) the teacher together with the students reflected on the process and evaluated the available solutions. The PBLPOE phase that contributes to improving students' critical thinking skills is the investigate and explain phase. The investigation stage involves students actively seeking information to solve various problems. The explain stage involves students actively discussing and explaining the

References	Type of research	Research subject	Data collection instruments	Data analysis methods	Results
(Azizah & Aloysius, 2023)	Quantitative research. Types of quantitative research are quasi-experimental designs	X Grade SHS students	test sheet	Correlation	comparison between the investigation results and predictions. The research results are that blended learning with the PBL-GI model effectively develops students' critical thinking.
(Isnaeni et al., 2021)	Quantitative research. Types of quantitative research are pre-experimental designs	XI Grade SHS students	test sheet	N-gain	Students' critical thinking abilities can be improved by learning using ICT-oriented PBL. The ICT-oriented PBL learning process is a critical thinking skills test using Quizizz. Quizizz makes the learning process more interactive, increases students' knowledge positively, makes students enthusiastic about understanding lessons, and can increase student independence.
(Don, 2020)	Quantitative research. Types of quantitative research are quasi-experimental	Undergraduate students	test sheet	t-test	Implementing PBL can improve students' critical thinking skills. The average N-gain of the PBL and control classes is 72.5 (medium) and 56.05 (medium). These results indicate an increase in student learning outcomes as much as the implementation of the teaching model. The PBL learning process trains students to design problems and explain or give examples. This encourages students' critical thinking skills.
(Boleng et al., 2018)	Qualitative research	XI Grade SHS students	questionnaire sheet	Percentage	The survey results showed that most teachers (86.0%) who already understood the learning approach stated that they understood, while the remaining 14% did not understand the Problem-Based Learning pattern. Apart from that, 23.3% of teachers said that students were less able to explain, express opinions, and make conclusions; 76.7% stated that students were quite capable of explaining, speaking, and drawing conclusions.
(Rahmatika et al., 2021)	Qualitative Research	Undergraduate students	test sheet	Percentage	The research results show that learning is still carried out through presentations and discussions. No learning process trains critical thinking. There is no availability of electronic teaching materials. Students' critical thinking abilities are still at a low level. Students have experienced difficulties taking Human Anatomy and Physiology courses, including abstract and complex material (64.5%), difficulty applying concepts in everyday life (22.6%), and lack of appropriate teaching materials. Relevant and easy to use in life (19.4%).

4. Discussion

4.1 Important information regarding the document

Rahmatika et al. (2021), highlighted that in biology learning, presentation and discussion methods are still the primary choices without paying attention to aspects of critical thinking learning, as well as a lack of accessible electronic teaching materials. This research also reveals that students' critical thinking skills are still low, as can be seen from

students' difficulties in taking Human Anatomy and Physiology courses. These obstacles include difficulty understanding abstract and complex material (64.5%), difficulty applying concepts in everyday life (22.6%), and lack of availability of teaching materials that are relevant and easy to use in life (19.4%). Presentation and discussion methods tend to provide knowledge passively to students because information is given to students without much direct interaction or research (Mo, 2023). As a result, students become recipients of data rather than actively thinking critically about what is conveyed (Jirana et al., 2020; Zulazhari et al., 2019). In addition, discussions can be limited if they are not facilitated well; students will only get information from some active people in the debate and others who are more passive. Additionally, these presentation and discussion methods do not provide enough opportunities for students to practice solving problems, using deductive reasoning, or generating hypotheses—all critical components of critical thinking. As a result, students do not receive adequate training to improve the required thinking skills, which can cause them to have low basic thinking skills.

On the other hand, the survey results reported by Boleng et al. (2018) revealed that 86.0% of teachers understood the concept of problem-based learning. Furthermore, the survey found that as many as 76.7% of students did not experience difficulty in explaining, expressing opinions, and making conclusions from biology learning material. From the results of this survey, it can be concluded that the teacher's ability to implement problem-based learning directly impacts students' ability to understand, express opinions, and complete biology learning material.

Problem-based learning has great potential to improve students' critical thinking skills because this learning model emphasizes the application of knowledge, analysis, synthesis, and evaluation (Sukacké et al., 2022). Problem-based learning presents students with real or complex problems that require critical thinking to discover problems, analyze data, and find practical solutions (Hartman & Gindy, 2010). They are also asked to think critically, consider various options, and evaluate the outcomes. Problem-based learning allows students to test their thinking, present their arguments, and hear different points of view through group discussions or collaboration (Hu & Chu, 2022; Ju et al., 2017; Saqr & López-Pernas, 2023; Si et al., 2019). In addition, problems posed in the real world or students' daily lives make them involved and motivated to solve these problems. Ultimately, this improves students' critical thinking skills (Chen, 2019; Latif et al., 2018; Massa et al., 2008; Poursharif et al., 2021).

4.2 What is the influence of the PBL learning model on the development of student's critical thinking skills in biology material?

The PBL (Problem-Based Learning) model has been proven to significantly affect the development of students' critical thinking skills (Jirana et al., 2020). A study shows that problem-based learning contributes 83.45% to increasing students' critical thinking abilities (Miterianifa et al., 2019). The N-gain value of the class that implemented PBL was also consistently higher, reaching 72.5, compared to the control class, which got 56.05 (Don, 2020). This finding aligns with other research that reports that students' critical thinking abilities increase by up to 73.81% with PBL compared to conventional learning (Boleng et al., 2017).

The PBL learning model influences students' critical thinking skills because PBL learning trains students to be active, collaborative, and centered on problem-solving (Abdullah et al., 2019; Desai et al., 2021). The PBL learning process encourages students to identify problems, collect data, develop hypotheses, and navigate data. Students learn material and gain critical thinking skills, such as logical analysis, evaluating information, and independent problem-solving. As a result, PBL improves students' critical thinking abilities through broad and challenging learning experiences.

Not only that, the PBL learning model has also been proven to be effective when supported by other learning models or learning media. For example, research by Azizah & Aloysius (2023) and Asyari et al. (2016) this research found that combining Problem-Based Learning (PBL) and Group Investigation (GI) learning models, called PBL-GI, can

strengthen learning syntax. The PBL-GI learning model trains students to conduct investigations in groups to identify problems in the surrounding environment and analyze and solve problems. Furthermore, the PBL-GI learning model has proven effective in improving students' critical thinking skills. Meanwhile, [Fitriani et al., \(2020\)](#) show that PBLPOE (Problem-Based Learning Process-Oriented Guided Inquiry Learning) significantly influences students' critical thinking abilities more than PBL and POE. Other research also states that the RANDAI learning model, which combines elements of Minangkabau culture with PBL, has a positive impact on student's critical thinking abilities, even showing significant differences between RANDAI, Problem-Based Learning and conventional class participants ([Arsih et al., 2021](#)).

Also, PBL oriented toward information and communication technology (ICT), such as Quizizz, has improved students' critical thinking skills ([Isnaeni et al., 2021](#)). Meanwhile, PBL with Fishbone Diagrams (FD) has proven effective in developing students' necessary thinking skills by facilitating identification and understanding of the causes of problems before solving them ([Priyadi & Suyanto, 2019](#)). Another report by [Adawiyah et al., \(2023\)](#) shows that PBL supported by Google Workspace can also improve students' critical thinking skills, with an average increase in scores in the experimental class reaching 19% -35%, compared to the control class, which only got 8% -23%.

The PBL learning model can also improve students' critical thinking skills when combined with other learning methods, models or media. This combination aims to enhance the quality of learning or overcome deficiencies in both. For example, combining the PBL learning model with the GI learning model and the POE method has proven effective. In this case, there is a significant increase in students' critical thinking abilities. Second, learning media, such as online platforms or information and communication technology (ICT), can make learning more interactive and exciting for students, thereby increasing student involvement in critical thinking activities. Third, using media like this can increase student involvement in critical thinking activities. Fourth, using learning models that reflect local culture, such as the RANDAI model, which combines elements of Minangkabau culture with PBL, will increase student engagement and increase the relevance and depth of the learning process. This effectively improves students' critical thinking skills. Therefore, the PBL learning model can significantly improve students' abilities in critical thinking if combined with learning approaches that are diverse and relevant to the current technological and cultural context.

4.3 What are the student activities in the PBL learning process?

PBL learning trains students to focus on a chosen problem to learn scientific concepts and methods related to that problem ([Miterianifa et al., 2019](#); [Don, 2020](#)). PBL steps involve analyzing and synthesizing data, developing hypotheses, applying deductive reasoning, and drawing conclusions while developing appropriate strategies to solve problems ([Boleng et al., 2017](#)). Thus, the PBL learning model encourages students to think critically, be active, and be responsible in completing their assignments ([Jirana et al., 2020](#)).

Students improve their critical thinking skills through PBL learning activities such as applying deductive reasoning, developing hypotheses, analyzing and synthesizing data, and drawing conclusions. First, students are taught data analysis and synthesis to compile and organize data and identify patterns or relationships between relevant data. Furthermore, hypothesis development encourages students to think critically and creatively in finding solutions by applying logic and the data they have. PBL helps students think critically and encourages them to explore, analyze, and evaluate data systematically and reflectively.

The PBL learning model can be strengthened by using media and other learning models, which aim to increase student learning activities in solving problems. For example, PBL learning models oriented towards information and communication technology (ICT), such as Quizizz, can make learning more interactive, raise enthusiasm, and increase student learning independence ([Isnaeni et al., 2021](#)). The PBL model supported by GI trains students to carefully plan, develop strong arguments, formulate

questions and problems correctly, analyze in-depth, and provide sustainable solutions to these problems (Asyari et al., 2016; Azizah & Aloysius, 2023). PBL with FD trains students to identify and understand the causes of problems before solving them, making problem-solving more accessible. Student activities in PBL with FD include analysis, discovery, and identification of factors that influence problems, determining more concrete solutions, building knowledge, and expressing and accepting opinions from others (Priyadi & Suyanto, 2019). The PBLPOE learning model, which combines PBL and POE learning steps, consists of six main activities: (1) the teacher distributes the text, and students actively formulate questions based on the book; (2) students are guided to sit in groups and choose the right questions to discuss, (3) the teacher helps students make predictions based on the problem, (4) the teacher facilitates group and individual student investigations, (5) students present the results of the investigation and compare them with predictions, and (6) the teacher together with students reflects on the process and evaluates solutions available (Fitriani et al., 2020). Apart from that, RANDAI (Minangkabau culture and PBL) learning follows six learning steps, namely: (1) Reciting, (2) Analyzing the problem, (3) Narrating the solution, (4) Doing the solution, (5) Assessing the solution, and (6) Implementing the solution (Arsih et al., 2021).

PBL learning becomes more interactive and relevant, enriching students' learning experiences using various learning models and media. This method changes how students understand information, ask questions, and seek solutions to problems. For example, by using information and communication technology (ICT), students can be directly involved in learning through games or interactive applications, which can increase their interest and drive to learn. In addition, learning models such as GI, FD, and PBLPOE offer a clear structure of the problem-solving process and help students improve their analysis, synthesis, and deductive reasoning skills. RANDAI learning that integrates cultural elements can increase the attractiveness of learning and make the material more relevant to students' daily lives. Therefore, PBL learning helps students understand concepts and teaches them to think critically, actively, and independently when solving complex problems.

5. Conclusions

Applying the PBL learning model is a pedagogical strategy that fosters students' ability to concentrate on a chosen topic, facilitating their understanding of the underlying concepts and scientific procedures related to the problem. The PBL learning model includes data analysis and synthesis, hypothesis production, application of deductive reasoning, and formulation of conclusions, all aimed at designing strategies to overcome existing challenges. The PBL learning approach prioritizes critical thinking, active involvement, and accountability among students in completing their assignments. Teachers can facilitate the implementation of the PBL learning paradigm by using various strategies and additional educational resources to increase students' critical thinking capacity. Therefore, instructors need to ensure optimal quality in the classroom learning process.

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